# Appendix D

# Threats to Submarine Cables

**Threats to Submarine Cables**

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## 1. ABSTRACT

While submarine cable systems are a highly reliable means for information transmission, faults due to external aggression are a major source of concern for both suppliers and system owners. This paper will first discuss historical trends in system fault experience, and then detail the nature of the threats from shipping and fishing activities. Finally, recommendations will be given for minimizing system vulnerability to such threats.

## 2. NATURAL AND HUMAN SOURCES OF CABLE FAULTS

Threats to submarine cable vary significantly for all cable landings dependent upon their geographical location. They result from a multiplicity of factors such as the presence of fishing grounds, the proximity of cable landing sites to busy harbours, waterways and associated anchorages and the length of the continental shelf and the system's routing to deep water.

Natural occurrences such as earthquakes and landslides have damaged cables, but the vast majority of cable faults are caused by human activity in the ocean. Data for the Atlantic Ocean and the Caribbean Sea from 1959 to 1996, presented in Figure 1, shows that less than 9% of all faults are caused by natural events. The peak in natural faults in 1986 is due to shark bite experienced in some of the first generation of optical fibre cables. This problem has been alleviated by the introduction of specially shielded cable designs.

In this and most of the subsequent figures, the fault data has been normalized by the number of kilometres of cable currently installed in depths less than 1000 metres, since most faults caused by human activity occur in this depth range. In Figure 1, the same normalization has been used for the natural fault data, even though such faults occur at all depths, in order to allow direct comparison of the curves.

The aggression by human activity can conveniently be divided into three categories:

- trawling and other net fishing;
- shellfishing on the seabed;
- anchoring.

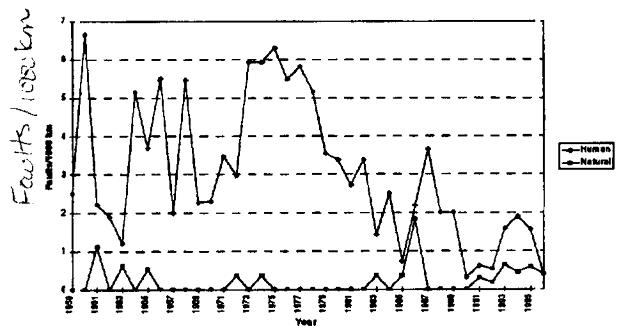


**Figure 1: Aggression faults normalized to cable length in < 1 km depth**

### 2.1 TRAWLING AND OTHER NET FISHING

The history of faults due to trawling and similar fishing activity is shown in Figure 2, separately for coaxial and fibre systems. The average fault rate for coaxial systems was approximately constant at about 3.7 faults per 1000 km per year from 1959 to 1979. The sharp decrease in the 1980 to 1985 period was due to the widespread burial of previously installed and new cable systems in fishing grounds. After 1985, the average fault rate was about 0.44 faults per 1000 km per year. This clearly demonstrates the benefit of cable burial in protecting the owners' investment.

1959-7
3.7/100
1985
0.44/10

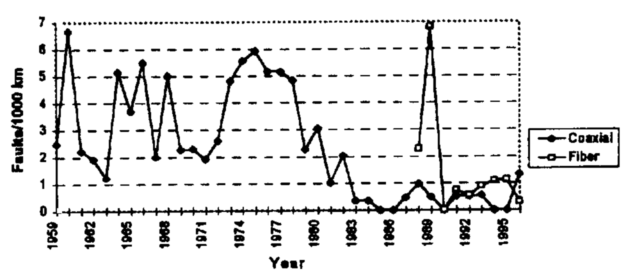


**Figure 2: Trawler and other net fishing faults normalized by cable in < 1 km depth**

The high number of faults in optical systems shown for 1988 and 1989 all occurred on TAT-8 in the eastern Atlantic, many in an area with shifting sand waves. Improvement in system burial resulted in the subsequent fault history of fibre systems being essentially the same as that of coaxial systems.

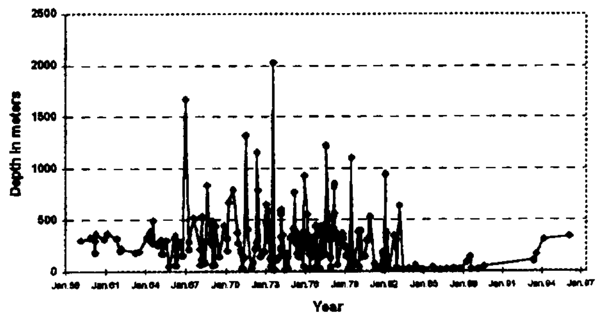


**Figure 3: Trawler damage depth history, coaxial systems**

An interesting history of the depth of trawler faults in coaxial systems is shown in Figure 3. Many faults occurred in depths less than 500 metres from 1967 until 1982, with a substantial number of faults in much deeper water. A review of the details of these faults reveals that most of them occurred on TAT-1 and TAT-2 in the heavily fished area of the Grand Banks off Canada. With the retirement of TAT-1 in 1978, the fault density decreases, and the faults nearly disappear with the retirement of TAT-2 in 1982. Data shows that deep-water fishing has been going on for many years in some areas, and emphasizes the importance of avoiding such areas where possible.

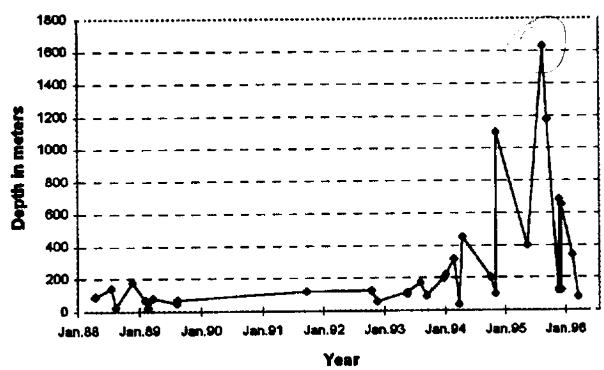


**Figure 4: Recent trawler damage depth history, coaxial and fiber systems**

After 1983, the curve has a very different character. Figure 4 shows the depth history of faults for both coaxial and fibre systems from 1988 to the present. Until 1994, fault depths were less than 200 metres. More recently, however, due to US and Canadian governmental fishing restrictions in shallower water in the western Atlantic, fishermen who have the necessary equipment have been working the deeper waters south of the Grand Banks and off the north eastern coast of the US. Cables have been damaged in depths close to the capability of today's towed plows. Such activity decreased in 1996, primarily due to the expense of deep-water fishing and the limited marketability of the species found. However, with improved equipment and with changing market tastes, deep-water fishing could readily increase in the future, resulting in more frequent attacks on unburied cables.

## 2.2 SHELLFISHING

Figure 5 shows fault data for sea-bottom shellfishing. Faults from this cause have occurred primarily in the western Atlantic, where such fishing is done over a wide area. The first aggression attributed to shellfishing happened in 1971, and such attacks continued for a number of years afterward. Even though the shellfishing equipment does not penetrate deeply into the seabed, the fishermen typically make repeated passes over the same area, so the total depth disturbed can be significant. In addition, equipment improved during this period and new species, notably quahog clams, became commercially marketable, resulting in expansion of the fishing grounds.

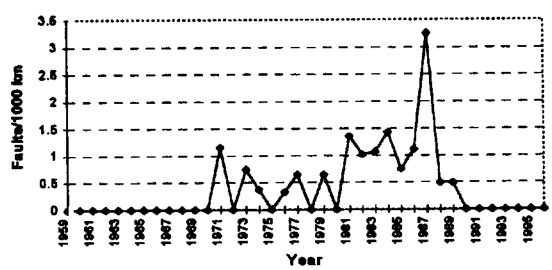


**Figure 5: Shellfishing normalized to cable length in < 1 km depth**

In response, more cable was buried, it was buried deeper, and some cables were rerouted from fishing grounds to unfishable, rocky areas. After a particularly bad experience in 1987, these measures were finally successful, and no faults have been reported from this cause in the Atlantic and Caribbean since 1990.

## 2.3 ANCHORING

Anchors are particularly damaging to cable systems because of their strength and because of the great depth to which they penetrate the bottom. Figure 6 presents total anchor fault experience for coaxial and fiber systems, and clearly shows a trend of increasing frequency of attack with time. It is also evident from this data that the extensive cable burial programs carried out in the early 1980s, which had a dramatic effect on trawler faults, had no effect on anchor attack. This is believed to be due to the fact that anchors can penetrate the seabed more effectively than towed cable plows.

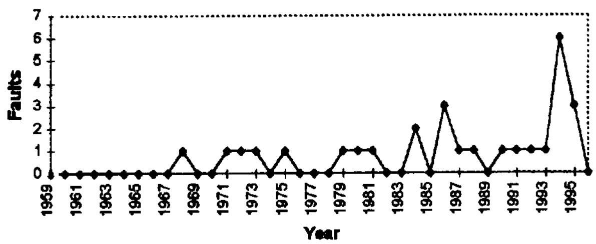


**Figure 6: Anchor faults, coaxial and fiber systems**

## 2.4 FAULT SOURCE SUMMARY

Statistical data shown in the previous sections indicates that human action is responsible for more than 90% of external agression faults and the specific nature of these is discussed in the following sections. The discussion relates largely to information gathered in relation to the North Atlantic but is generally applicable worldwide.

## 3. THE THREAT FROM FISHING

The overall threat from fishing activity derives from a combination of the seabed penetration of each method, the power of the vessels involved and the areas over which they operate. Of the methods currently in use, trawling is considered the greatest threat to cables, although bottom set fixed fishing gear and dredges also pose a significant risk. This section briefly outlines various fishing methods with particular emphasis on the extent to which they may interfere with cables by penetration of the gear. Also discussed are the areas of operation for each method and how these are changing.

Whilst cable burial to a target depth of 0.6 to 1 metre into the seabed in water depths down to 1000 metres has resulted in a substantial reduction in the number of fishing related cable incidents on new systems, the increasing demand for fish and shellfish throughout the world shows that fishing methods capable of damaging cable are spreading to deeper waters as more traditional fisheries decline and new resources are exploited.

### 3.1 TRAWLING

Trawling is the most widespread form of fishing, utilising by far the largest number of vessels and covering a larger area of the seabed per trip than any other method. Furthermore, it utilises the most powerful vessels, and with modern trawlers generating a towing force of around 130 kN per 1000 kW of vessel power it is not surprising that bottom trawling is the most commonly reported cause of fishing-related cable damage. Demersal otter trawling probably constitutes the biggest single risk group to cable. However, other forms of trawling also pose a threat including, beam trawling and twin trawling but it should be appreciated that fishermen aim to operate their equipment on or above the seabed, not below it. A brief description of the various forms of trawling is provided, based on European methodologies. It should be appreciated however that equipment, procedures, fishing depths and regulations do vary with geographic location.

The otter trawl consists of a wide net, held open by a pair of otter boards or doors, and towed along the seabed at speeds of up to 4.0 knots, by vessels ranging in power from 100 kW to 3000 kW. Contact of the catching net with the seabed is maintained by a variety of chains and ground gear. The main threat this arrangement poses to cables is impact and entanglement with either of the otter boards. The chances of this occurring are increased if the boards are damaged or badly maintained or if additional weights are added to the shoe plate.

Although otter boards can weigh up to 3500 kg, they are designed to skim the surface of the seabed and in normal circumstances would not be expected to penetrate by more than 50 mm. Nevertheless, evidence from board wear does suggest that in very soft ground they can penetrate up to 300mm. However, such penetration results in increased tow tensions and consequently is to be avoided to prevent sediment entering the trawl, and, given that good burial is achieved in such ground, the risk lies largely in areas where cable burial is unreliable or unachievable. Only a minimal risk reduction is achieved by additional cable armouring at or near the surface in regions where powerful vessels are operating.

Beam trawling utilises two identical beam trawls towed over the seabed at speeds of up to 6 knots from port and starboard derrick booms, at depths generally less than 100 metres. The mouth of each trawl net is held open by a heavy tubular beam supported at its ends by triangular shaped shoes. There are approximately 750 vessels in the European Atlantic Fishery, which range in power from 150 to 1900 kW. Beam trawling is closely regulated by the European Union fisheries policy which includes placing a limit of 12 metres on the maximum permissible beam width. The main threat to cables is impact from the base of the shoes and possible entanglement with the ancillary gear. Beam trawling has been responsible for many cable faults and much of the current fault data in the North Sea relates to surface laid cables being hooked by unmodified trawls. The risk of hooking cable has been reduced in recent years by modifying the shoes to fit fenders or rounded fronts to the leading edges.

Beam trawling constitutes a lower risk than otter trawling. The worst case estimate for beam trawl penetration is quoted as 150 mm and the threat is further reduced by the tendency of the front edge of the trawl shoes to lift off the bottom, when towed at speed.

Whilst beam trawling may be diminishing as a threat, there may be an increasing threat in the form of twin trawling. This consists of two identical trawls towed by a single vessel on two or three warps. The trawl mouth opening is achieved by otter boards on the outer wings and a heavy clump weight or sled linking the inner wings. The method is primarily targeted at shrimp. New, heavier trawls, are being used to target hake in arctic and sub-arctic regions. These trawls have also been found suitable for other bottom feeding fish and can therefore be reasonably expected to become more widely used in the future.

Twin trawling is on the increase, but as yet no precise information is available on the intrusion this makes into the seabed. The opinion is that the outer otter boards are probably subject to the same 300 mm maximum as single trawling. The greater concern arises from recent developments where the triangular centre clump weight, which, although fitted with bottom rollers, may weigh up to 7 tonnes and thus be prone to sinkage in soft grounds.

### 3.2 DREDGES

Dredging is the generic term describing a number of towed fishing gears which are designed to dig into the sediments to harvest shellfish in water depths down to 100 metres. They may be of the so-called 'dry' type which consist of a rectangular frame with a toothed bar on the leading edge, combined with a netting bag or of the mechanised hydraulic or 'wet' dredge type, which fluidises the seabed ahead of the dredge and pumps the slurry through a separating device to recover marketable shellfish.

There have been a number of faults in surface laid cable attributed to this type of fishing activity, especially clam dredging, off the east coast of the US.

'Dry' dredges are designed to disturb the substrate to a depth of about 150 mm. In 'wet' dredges, penetration of the scraper blade is about 200 mm, but the liquefaction process can extend down to about 300 mm. The worst case situation relates to Quahog dredging where the equipment may penetrate the seabed to a depth of 450 mm. The threat is further increased from repeated dredging operations over the same ground that may erode the seabed to the extent that cables initially buried to 0.6 metres become exposed.

### 3.3 BOTTOM SET FIXED FISHING

These are passive fishing methods in which gear is anchored to the seabed to catch fish during their feeding or migratory movements. They include longlines, vertical lines, bottom set nets including stow nets and traps or pots. There are two threats to cables from this type of fishing as follows:

- damage from fishing gear anchors;

- damage to lightweight cables from fishing hooks.

The largest fishing anchors identified in a recent North Atlantic survey, were 85 kg with a maximum fluke length of 800 mm, although most ranged from 25 to 50 kg. A limiting factor on the damage they can inflict is set by the breaking strength of the anchor wire, typically around 50 kN.

The notable exception is stow (or fyke) net fishing largely carried out in Korean waters, where the use of heavy anchors in soft ground is a proven hazard to cables. The gear consists of a conical net up to 100 metres in length in which the mouth is held open by a tubular framework. They may have netting wings to shepherd the fish into the mouth. The stow net depends on a strong and persistent current along which the fish make a daily migration. The net may be attended by a vessel, which as well as hauling the daily catch, can raise or lower the net into the path of migratory fish. The net is held in position by anchors weighing up to 1500 kg that will also hold the vessel in position.

Penetration from the majority of anchors used in fixed net fishing is likely to be small. The maximum penetration of these anchors would be about 1.1 times the fluke length and the threat is further reduced by the common practice of using anchors that allow easy recovery in the event of fouling. The exception is the practice of stow net fishing in shallow water where the largest anchors used may penetrate good ground by up to 1.5 metres, and soft ground by up to 2.7 metres, as measured by Travocean for Alcatel, following a power cable fault south of Korea attributed to stow net fishing. A key factor in the high risk they present is that the frequency of deployment and retrieval of stow net anchors is much higher than normal ship anchoring procedures.

### 3.4 LONGLINES

Although only a few cable faults have been attributed to longlines, these continue to pose a hazard, particularly during cable installation; lightweight cables being most at risk as the use of longlines is increasing in deep-water fisheries. The main line of a longline is laid horizontally on or just above the seabed and can extend up to 13 km and carry up to 8400 steel hooks. Vertical lines are similar to longlines except, as their name suggests, they are deployed vertically. The risks from this type of fishing are: where the size and design of the hook are such that it can penetrate deeply into the cable insulation; the use of mainline anchors, and, when grapnels are used to recover gear.

Deep water longlines tend to employ large anchors but fault statistics suggest that the threat from longlines tends to be from hooks rather than from anchors.

### 3.5 AREAS AND DEPTHS OF FISHING ACTIVITY

Otter trawling is practised widely over the continental shelf on both sides of the Atlantic. Since 1990 there has been an increase in the number of trawlers fishing the continental slopes down to 1700 metres, and more recently, the seamounts of the mid-Atlantic and Reykjanes ridge. Progression beyond 1700 metres cannot be ruled out, but the eventual biological limit is considered to be 2500 metres. The power of the vessels exploring deep water lies in the range 1000 to 3000 kW in order to handle the extra weight of long, high strength towing warps, heavy boards and mid-oceanic weather conditions.

Although the location of deep-water fisheries is ever-changing, the current situation on trawling for the north Atlantic, i.e. at water depths in excess of 500 metres, is shown in Figure 7, together with other forms of fishing activity considered a threat to cable.

Many hundreds of vessels are engaged in twin trawling over an arc extending around the Atlantic rim from Florida to Shetland. Most are less than 300 kW, but a developing threat to cables comes from an increasing number of larger vessels of up to 3000 kW, fishing depths down to 900 metres. The largest vessels are at present confined to the Flemish Cap area and East Greenland but successful exploitation of deep-water shrimp there could lead to expansion of fisheries in other parts of the North Atlantic.

Various passive methods of fishing are carried out all around the Atlantic rim and on the mid-Atlantic ridge. The areas considered to be at most risk from longlines and vertical lines are also shown on Figure 7, in depths down to 1700 metres, although some Antarctic longlines are currently being set to 2500 metres.

'Dry' dredging is widely used around the Atlantic rim, but only in depths down to about 100 metres. 'Wet' dredging is mainly confined to the east coast of the US down to 100 metres and some very shallow areas of the Dutch and British coasts.

Stow net fishing is confined at present to the Far East, particularly off the south and west coast of Korea, in water 20 to 60 metres deep.

## 4. ANCHOR THREATS

Anchors are used for a wide variety of tasks ranging from the positioning of fishing gear through to the mooring of large merchant ships and the permanent fixture of offshore platforms used in the oil industry. We have even encountered a fault caused by a meteorological buoy dragging its anchor, although such events are rare.

The threat to undersea cable from such diverse applications differs widely and is discussed in more detail in this section, with the emphasis again placed on seabed penetration. However, statistics do indicate that the threat from anchors diminishes sharply with water depth to around 150 metres, beyond which anchor faults are virtually unknown.

### 4.1 ANCHORS FOR USE WITH FISHING GEAR

There are various forms of fishing that involve anchoring gear to the bottom. These include longlines, vertical lines, bottom set nets, traps or pots and fish aggregation devices (FADS). The largest anchors for these applications are, however, less than 100 kg in weight,

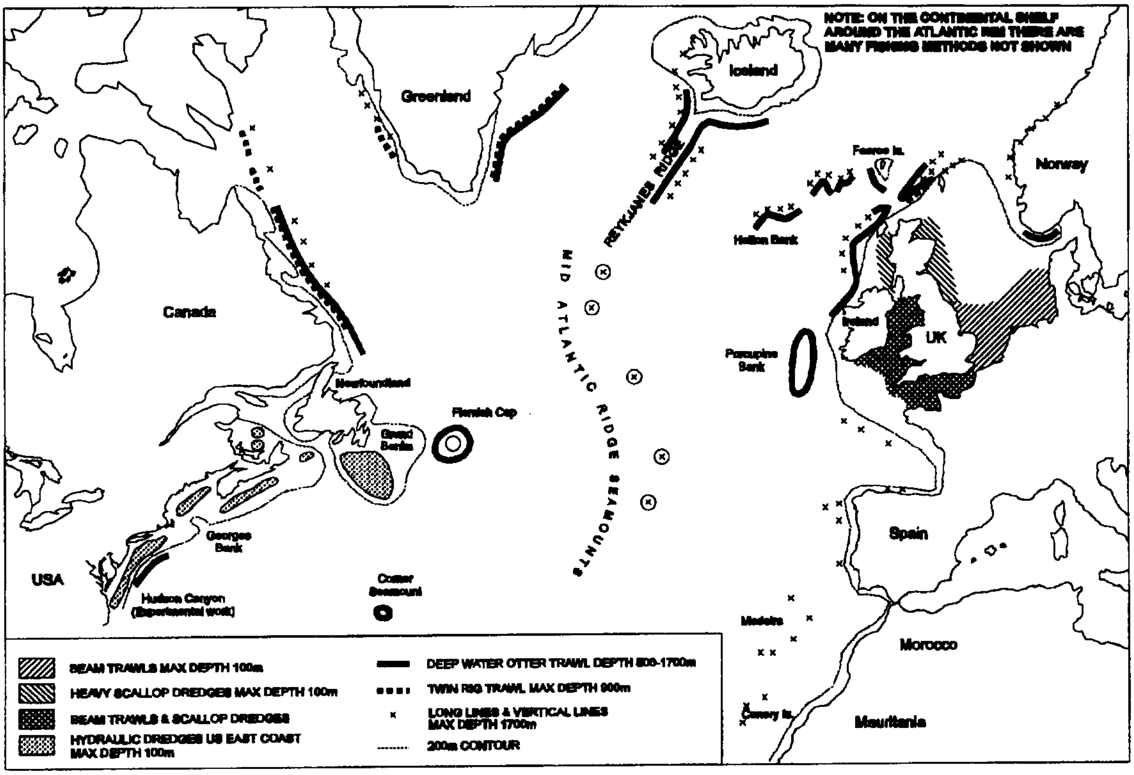


**Figure 7: Fishing threat in the North Atlantic**

and although capable of penetrating the seabed by up to 1 metre, would generally represent a low risk to a buried submarine cable. A notable exception is the practice in the Far East of stow net fishing in which anchors up to 1500 kg in weight and fluke lengths of 1.5 metres may be used. FADS are confined to tropical and sub-tropical waters in the Far East and Pacific.

## 4.2 PERMANENT MOORINGS

Anchors used with these structures are designed to produce very high holding power, without the normal constraints of ease of recovery and handling imposed by normal ships' use. These anchors have to be placed very carefully in position on the seabed and then remain in place for long periods. Extensive development has improved the performance of these anchors and whilst they may penetrate several metres into the seabed, they do so over short distances in pre-planned positions where their users should have a good awareness of cable installations. Unless the structure breaks free in extreme weather conditions, this type of anchor does not represent a major risk to submarine cables, and the fault statistics gathered to date support this.

## 4.3 SHIPS' ANCHORS

This class of anchor poses by far the greatest threat to cable. The world fleet, as described by its Gross Registered Tonnage (GRT) in Lloyds Register of Shipping, contains 83,000 vessels ranging from 100 GRT to 150,000+ GRT. An analysis of a sizeable sample from the register has been used to produce the relationship between gross tonnage of the vessel and the weight of its anchor.

In order to scope the overall threat of cable damage from ships' anchors it is necessary to examine more closely design features of anchors, their size distribution for various applications and how these affect penetration into the seabed. There is a vast selection of ships' anchors available but the majority of anchors on modern vessels are the bow (or bower) type, of which the "stockless" type shown in Figure 8 is the most common. The most modern large vessels now employ a high holding power variation of this design. These are popular because they allow a 25% weight concession by virtue of their increased efficiency, thus easing space and cost considerations. Examples of these are Stokes, Danforth and Admiralty Cast (AC) designs. The improved performance is achieved by greater penetration into the seabed.

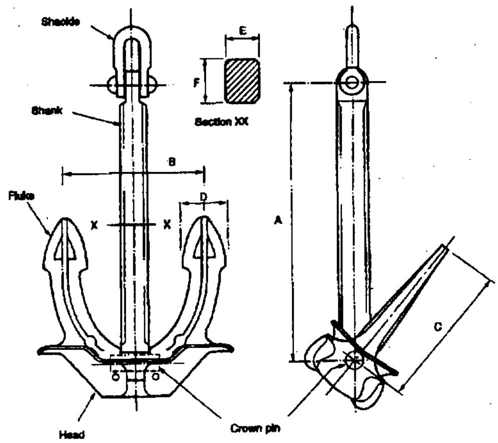


**Figure 8: Stockless anchor details**

The most important parameters to anchor users are holding power and the drag distance needed to realise full holding power. Direct measurements of the penetration into the seabed are therefore not often reported in the literature. However, a comprehensive study of anchor performance was carried out by NCEL (1) for the US Navy and this included penetration data for a group of drag anchors as shown in Figure 9. In addition, information from Lloyds Register on anchor size versus vessel size and dimensional details from anchor manufacturers allows the relationship between seabed penetration into firm ground and ships gross tonnage to be estimated (Figure 10).

Practical trials have demonstrated that maximum holding power is achieved with a fluke angle of $32^0$ in gravel, whereas the optimum for soft mud is $50^0$. Manufacturers often use $40^0$ as a compromise for all types of seabed. A fluke angle of $40^0$ will limit the vertical penetration in good ground, where the stock remains horizontal on the surface, to the fluke length x sin $40^0$.

In general, ships anchor in good ground with anchor penetration in the region of one fluke length, equivalent to around 2.2 metres for the largest anchors. Of course, in the extreme circumstances of anchoring on a soft seabed, greater penetration is to be expected. Take, for example, a 5,000 GST vessel with a 4 tonne stockless anchor; the anchor would have a fluke length of about 1.6 metres, and from Figure 9 would be expected to penetrate into soft mud by 5 metres.

The risk of an anchor hooking a cable is not only related to its penetration, but also to the distance over which it disturbs the seabed. The initial drag distance required by an anchor to develop its full holding capacity is therefore

| Anchor Type | Sands/ Stiff Clays | Mud/ Soft Silts/ Clay |
|---|---|---|
| Stockless | 1 | 3 |
| Moorfast<br>Offdrill 2 | 1 | 4 |
| Boss<br>Danforth<br>Flipper Delta<br>GS Type 2<br>LWT<br>Stato<br>Stevfix*<br>Stevpris* | 1 | 4.5 |
| Bruce*<br>Bruce TS*<br>Hook*<br>Stevmud* | 1 | 5 |

* anchors more appropriate to permanent moorings.

**Figure 9: Fluke Tip Penetration in multiples of fluke length**

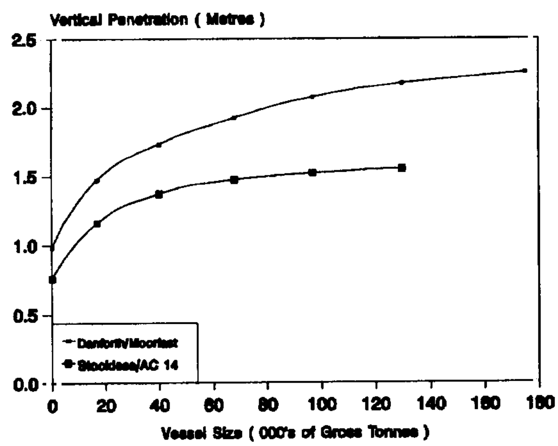


**Figure 10: Anchor penetration versus vessel size for firm ground**

an important parameter governing the risk to submarine cables. In this respect, many anchors are similar in taking 20 to 30 times the fluke length to reach 90% of their full pull-out strength. This means that the chance of hooking a cable increases with anchor size by virtue of both its penetration and its drag distance. Another factor in determining the risk, is the behaviour of an anchor when conditions exist to cause it to be dragged by a vessel. This will normally cause the anchor to break out by rotation, only for continued drag to cause it to re-penetrate. This situation obviously constitutes a high risk, should it continue over a long distance. Although there have been accounts in the past of this causing multiple faults on surface laid coaxial cables, it is not considered a common occurrence, considering the number and spacing of cable installations.

## 5. MINIMISING THE THREAT FROM FISHING AND ANCHORS

Past experience has shown that re-routing has been effective in eliminating the threat from shellfishing in the Western Atlantic but in order to further reduce the number of cable faults attributed to fishing in general, more consistent burial techniques are required to ensure that the cable remains below the threat line of 0.3 metres. Furthermore, burial should be extended to counteract the development of fishing in deeper waters, again adjusting the burial depth in accordance with the seabed penetration of fishing activity. Detailed studies of the intensity of shipping activity to determine the density of vessels and their size, will enable estimates to be made of the size and hence penetration depth distribution of their anchors. This process should lead to a recommendation for burial to a depth to place the cable substantially beneath the anchor threat line, perhaps as deep as 3 metres in particularly vulnerable areas, in water depths down to 150 metres. An example of a future burial line taking account of all perceived risks is shown in Figure 11. Where the depth profile of the route is such that extensive sections of cable lie within the 150 metre depth contour, this policy may be waived where the threat is considered negligible, for example where distance from the coastline means that anchoring is extremely unlikely.

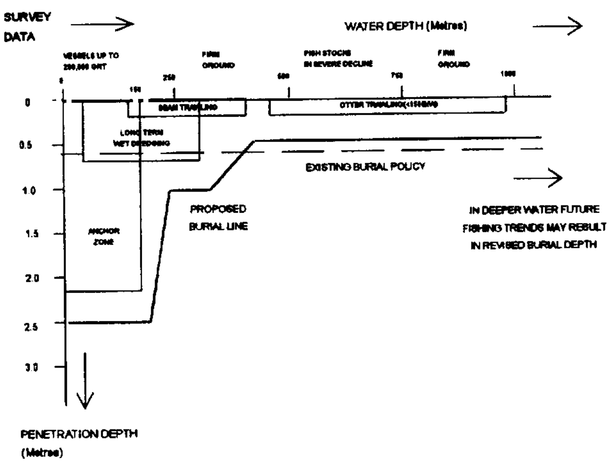


**Figure 11: Example of concept of adusting burial depth to remain below threat line**

Fault statistics suggest that the shortest route to 150 metres water depth will further reduce the risk of anchor faults. Avoidance of anchor zones, especially those which coincide with easily penetrable seabeds, will further reduce the incidence of such faults. Furthermore, developments in the use of satellite surveillance to determine the extent to which vessels observe anchoring zones may also provide useful information.

## 6. CONCLUSION

Analysis of the historical data indicates that the fault records of fibre and coaxial systems are similar and that whilst cable burial 0.6 to 1 metre below the seabed provides a very effective means of protecting cable against fishing activity, it is ineffective against anchors in soft sediment.

Fishing is moving deeper, beyond the range of the present towed ploughs and this trend is likely to continue because of the conservation of shallow-water species. Otter and twin trawling in particular represent a developing threat in slope areas and around sea mounts down to 1700 metres at the present time, although these may extend even deeper. Of the remaining fishing activities, stow net anchors, mechanised hydraulic dredges and longline hooks remain as additional significant threats.

After reviewing all types of anchors it is concluded that ships' anchors represent by far the highest threat to cable. Studies of the size distribution of the world fleet, anchor designs and seabed penetration indicate that anchors capable of exceeding current cable burial depths are quite common.

In order to minimise the threat from fishing and anchors for future systems, a contract-specific burial policy is required that places cable below the perceived threat line. Establishing this threat line will require greater attention to survey data and a more detailed knowledge of local fishing and shipping activities. However, the additional costs involved should be more than covered by the improvement in system security.

## 7. ACKNOWLEDGEMENT

The authors would like to thank their colleagues in CWM and KDD-SCS for the discussions and contributions towards compiling this paper.

## 8. REFERENCES

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